FLUID METERING WITH A DISPOSABLE MEMBRANE TYPE PUMP UNIT

This invention relates to improvements in fluid metering and especially, but not exclusively, to the sanitary metering of very viscous fluids, for example beverage concentrates.

In the food sector, for example, there is often a requirement to dispense a metered amount of fluid foodstuff for use as such or in admixture with a diluent such as water. It is becoming increasingly important to be able to dispense fluids in a sanitary manner where there is no possibility of outside contamination of the fluid foodstuff or where companies want to be able to assure the integrity of the fluid being dispensed. Commonly, the fluid foodstuff is supplied in a disposable container. For sanitary requirements to be met, it is desirable that the fluid contacts only disposable parts of the system, including the pump used to dispense the fluid. For this to be economically viable, the pumping method should be simple and so relatively inexpensive to produce.

In food dispense, and particularly in the beverage industry, there is a common requirement to dispense an accurate ratiometric mixture of a concentrate and a diluent. Common technologies involve measuring the flow of the concentrate and then varying the diluent flow to achieve the correct mixture. This has the disadvantage that it involves measuring the fluid flow of, in particular, the concentrate. Common methods include the use of turbine flow meters and differential pressure flow meters. These techniques are however not effective for measuring the flow of a highly viscous concentrate such as an orange juice concentrate. Current methods of dealing with these viscous fluids are to meter them using peristaltic pumps or diaphragm type pumps integrated into manifolds. While these methods work well for many relatively viscous fluids, they do not work well for very highly viscous fluids. For example, peristaltic type pumps typically become less effective for fluids having a viscosity in excess of about 5000 centipoises. Non-disposable diaphragm pumps can be effective for dispensing very viscous fluids but the manifold valving arrangements for disposable sanitary diaphragm pumps are

commonly such that the fluid drag renders them unsuitable for use with very viscous fluids.

Examples of disposable sanitary diaphragm pump designs are proposed in US Patent 6,485,263. However, these designs either utilise somewhat tortuous fluid inlet paths and additionally require simultaneous control of different pressures to the three parts of the pump - inlet valve, pump chamber and outlet valve (eg as shown in Fig 10) or, alternatively, they utilise solenoid valves (e.g. as shown in Fig 1) that are intended to be disposed of with the other disposable pump components. The tortuous inlet path shown in the Fig 10 proposal would create considerable drag on a highly viscous fluid and hinder the performance of the pump resulting in a pump which is very limited in operating speed. This problem could be overcome by pressurising the source of fluid that is being dispensed by applying pressure internally to the fluid reservoir or by having a flexible reservoir and applying pressure externally. However, in sanitary systems, it is not acceptable to apply internal pressure and to apply pressure externally involves a much more complex and expensive system. The use of solenoid valves in the pump unit intended to be disposed of, as shown in Fig 1, has the disadvantage that they are expensive.

It is the purpose of the present invention to provide an improved sanitary fluid metering device which incorporates a relatively cost-effective disposable pump arrangement and which is capable of metering a highly viscous fluid.

According to a first aspect of the present invention, there is provided a disposable pump unit for receiving and metering a predetermined volume of fluid, the pump comprising a body having a surface at which opens the mouth of a cavity formed in the body, an inlet port for the fluid opening at the surface adjacent to the mouth of the cavity whereby, when the inlet port is open, fluid can flow from the inlet port into the cavity *via* the mouth thereof, a first flexible membrane sealingly secured at its periphery to the surface and overlying the cavity and the inlet port, an outlet port for the fluid , there being a fluid flow passageway extending through the body connecting the cavity to the outlet port, and a second flexible membrane sealingly secured at its

periphery and overlying the outlet port, those portions of the first and second flexible membranes, where they overlie the inlet and outlet ports respectively, serving as closures for the ports.

The outlet port preferably also opens at the aforesaid surface, in which case the first and second flexible membranes may be integral with one another. Preferably, at least the first flexible membrane, i.e. the membrane that overlies the cavity and the inlet port formed in the body, is substantially non-stretchable and is dimensioned such that, during the fluid metering step, it can be urged by the actuating fluid into contact with substantially the whole surface of the cavity wall whereby substantially all of the fluid drawn from the reservoir during the fluid filling step is pumped out during the fluid metering step. To that end, the first flexible membrane (and the second flexible membrane where the two are integral with one another) may, for example, comprise polyamide film material. In a preferred embodiment, at least the first flexible membrane comprises a flexible film or sheet of an integrated laminate comprising a non-stretchable polymer, for example a polyamide, and an underlying heat-weldable polymer, for example a food-grade polyethylene, the latter having been heat-welded to the body so as to be sealingly secured thereto as aforesaid with the body comprising a moulding in a compatible food-grade polymer, for example a polyethylene. An example of a suitable laminate is S77 available from Amcor Flexibles Baricol. Preferably the laminate is preformed to a shape substantially similar to the shape of the surface of the pump cavity, such that it substantially fully evacuates the cavity without the need for the membrane material to stretch. Preferably during storage and transportation the preformed shape of the laminate film lies flush with the concavely curved surface of the pump cavity thereby reducing the susceptibility of the membrane to damage during transit.

In use, and in accordance with a second aspect of the invention, a disposable pump unit of the invention is detachably coupled to a re-usable pump actuator, with the said surface sealingly abutting the pump actuator, comprising a source of positive and negative pressure actuating fluid, preferably air, and first and second valve actuating means associated respectively with the inlet port closure and the outlet port closure,

the arrangement being such that, when the external surface of the first flexible membrane (which acts as a pumping membrane) is exposed to the source of negative pressure fluid, with the inlet port open and the outlet port closed, it is drawn away from the disposable pump body whereby fluid, such as a beverage concentrate, is drawn, from a reservoir thereof *via* the inlet port, into substantially all of the space defined by the cavity and the first flexible membrane ("the fluid filling step"). Then, with the inlet port closed and the outlet port open, when positive pressure fluid is applied to the external surface of the first flexible membrane, the membrane is urged back towards and into the cavity and pumps the fluid from the cavity through the said passageway to the outlet port ("the fluid metering step"). There may be a variable downstream flow restrictor to enable the same fluid metering rate to be achieved for different viscosity fluids with the application of the same positive actuating fluid pressure. Alternatively, the fluid pressure could simply be varied or a combination of variable downstream flow restrictor and variable fluid pressure could be used. The aforementioned variable restrictors and or pressure allow the outlet flow of the pumped fluid to be varied, or alternatively allow the output flow to be maintained substantially constant while fluid properties, for example temperature, change.

The first valve actuating means associated with the inlet port closure is preferably an axially movable armature that extends into the volume subject to positive and negative pressure and seal is provided where the armature protrudes into that volume; preferably the seal is a rolling diaphragm type seal. The second valve actuating means is likewise preferably an axially movable armature and a like seal may also be provided. Provision of these seals additionally prevents dirt ingress into the valve actuators and enables use of cleaning fluids without the danger of the fluids affecting the valve actuators, which may be electrically driven.

Preferably, a disposable pump unit of the invention comprises a body having a plurality of cavities each having respective inlet ports, outlet ports and flexible membranes whereby, when coupled to a pump actuator, fluid may be drawn into at least one of the cavities whilst simultaneously being pumped out of another. In this way, the unit may, where required, be used to meter varying predetermined volumes

of fluid in a substantially continuous and efficient way. Preferably, the body has a pair of cavities. Where there is a plurality of cavities, the simultaneous fluid filling and fluid metering steps may be of different duration such that when one dispensing step from one of the cavities is complete the other is ready to commence, or has already commenced, its dispensing step; this may be achieved by, for example, suitably adjusting the negative and positive actuating fluid pressures by means of adjustable pressure regulators.

Preferably, in a disposable pump unit of the invention, the fluid flow passageway extending through the body and connecting the cavity to the outlet port terminates at one end at a generally concave wall defining the cavity, the wall having formed therein a plurality of passageways that communicate with the fluid flow passageway thereby to inhibit, during the fluid metering step, the formation of occluded regions of fluid between the cavity wall and the first flexible membrane and thus ensure that substantially all of the fluid drawn from the reservoir thereof during the fluid filling step is pumped out during the fluid metering step. Each of the plurality of passageways is preferably a groove.

The combination of a disposable pump unit of the invention and a re-usable pump actuator may constitute a beverage dispenser as is more particularly described in our co-pending PCT application of even date, the pump unit serving to meter a predetermined amount of a beverage concentrate, for example orange concentrate, which is then mixed with water, preferably in a predetermined ratio, delivered by the dispenser. For that purpose in particular, the body of the disposable pump unit preferably incorporates a diluent, e.g. water, inlet communicating with an outlet passageway formed in the body connected to the outlet port whereby, as fluid flows from the outlet port through the outlet passageway, it mixes with the diluent and is then dispensed into a receptacle such as a cup or glass. Preferably downstream of the outlet port of the pump cavity and immediately upstream of the diluent inlet are a number of obstructions in the flow path adapted to break up of the pumped viscous fluid to aid mixing with the diluent. The outlet passageway preferably includes means, for example a static turbulator, to assist the admixture of the fluid and diluent.

Further, there may be provided means to adjust the diluent flow rate and feedback means so as to ensure substantially constant ratiometric mixing at a target dispense rate.

The pump actuator includes a complementary surface that abuts the aforesaid surface of the disposable pump unit. Both surfaces are preferably substantially planar. An essential function of the pump actuator surface is to control the degree to which the first flexible membrane can be drawn away from the disposable pump body and therefore in part to define the predetermined metered volume of fluid. Preferably, the surface of the pump actuator also has at least one recess (the number corresponding to the number of cavities in the disposable pump body) defined in it for receiving the first flexible membrane during the fluid filling step, the recess wall serving to limit movement of the membrane. The cavity(ies) of the disposable pump unit and recess(es) (if any) of the pump actuator are preferably concave in form.

Preferably, each pump actuator has associated with each recess a means of detecting whether the or each recess is full of fluid or is empty. Preferably the detecting means comprises ultrasonic transducers, the variance in signals from which indicate the volume of fluid within each recess.

Another function of the pump actuator is to provide actuating means for the closures of the inlet and outlet ports. The actuating means for the inlet preferably comprises a solenoid-operated armature which, by means of a compression spring, urge part of the respective flexible membrane into sealing contact with the inlet port in order to close it, but which assume, when the solenoid is energised, a spaced position from the membrane when the port is required to be open. It will be recognised to those skilled in the art that other conventional actuation means, for example pneumatic, could be used to drive the armature in place of the solenoid described above. In a preferred arrangement the valve actuating means associated with the outlet port closure is capable of affecting a variable, pre-selected, degree of opening of the outlet port. This may be achieved by using, for example, a stepper motor or a variable end stop solenoid associated with an armature or other actuator that acts upon the second

flexible membrane where it overlies the outlet port. This feature enables the disposable pump unit to control the outlet flow rate as desired depending upon the viscosity of the fluid being metered. For example, with a relatively higher viscosity fluid, it may be desirable to have the outlet fully open in order to achieve the desired outlet flow rate and hence the required ratiometric mixing control with a diluent such as water, whereas with a relatively lower viscosity fluid it may be desirable to have the outlet only partially open for that purpose.
Alternatively, for example, the armatures may be pneumatically operated. In order to improve the fluid seal between the ports and the flexible membranes in the port-closed position, each port is preferably surrounded by a raised lip. Preferably the actuating means are provided with soft tips, for example of a silicone rubber, which do not damage the membrane and provide an even pressure on the raised lip.

The disposable pump unit is preferably permanently connected to, or integral with, a reservoir containing the fluid so that, once the reservoir is empty or otherwise needs to be changed, the combined reservoir and pump unit are disconnected from the pump actuator and may be disposed of. A replacement reservoir/pump unit may then be connected to the pump actuator. Preferably a closure is provided between the pump unit and the reservoir such that the reservoir and disposable pump unit may be shipped together whilst preventing the migration of fluid into the disposable pump unit. Once in situ and connected to the pump actuator the closure is moved from a closed position in which flow between reservoir and disposable pump unit is blocked to an open position in which fluid may flow from the reservoir to the disposable pump unit. Especially in the drinks dispense context, the reservoir and disposable pump unit is preferably refrigerated by a refrigeration system comprised in the re-usable part of a drinks dispense machine and which may also serves to cool said diluent. In a preferred arrangement, the action of loading and unloading the disposable pump unit from the pump actuator automatically opens and closes the closure respectively.

It will be appreciated that the metered fluid comes into contact with only components of the disposable pump unit and, therefore, that the pump actuator may be continually

re-used without the need to clean it regularly. Thus, the pump actuator will be part of, for example, a fixed drinks dispense machine installed in a bar, restaurant or the like, it being possible for a given machine to dispense different beverages depending on the nature of the fluid concentrate contained in a selected reservoir/disposable pump unit. Because different concentrates will usually require different degrees of dilution, the disposable pump unit preferably includes an identification means and the re-usable pump actuator includes reading means for automatically reading the identification means whereby the combined pump/pump actuator, for example a drinks dispense machine, may adapt its dispense mode, e.g. diluent flow rate, and/or provide audio and/or visual information to the user in dependence upon the characteristics identified. Such characteristics may include, for example, one or more of the viscosity of the fluid to be metered in a particular case, its type (e.g. orange juice or otherwise), its shelf-life/expiry date and the desired dilution ratio. The identification means and the reading means may be based on, for example, radio frequency identification (RDIF) technology, Electro-Erasable-Programmable-Read Only Memory (EEPROM) chips, bar code technology or colour-sensing technology, the general nature of all of which are known. Preferably the reusable pump actuator has associated therewith a read/write device that is capable of both reading information from an identification means associated with the disposable pump unit and writing information to said identification means.

According to a third aspect of the present invention, there is provided a disposable pump unit as defined above adapted for mixing two or more fluids, especially viscous fluids, the body defining two or more said cavities and an inlet port associated with each cavity and with reservoirs for the respective fluids, and a common outlet associated with the cavities, whereby the fluids may, in association with a re-usable pump actuator, be dispensed simultaneously and mixed. Such a unit has a number of diverse applications, and we mention by way of example the mixing of the two precursor materials of epoxy resins (e.g. "Araldite" – Registered Trade Mark).

Embodiments of the invention will now be described by way of example only, with reference to the accompanying drawings in which;

Figure 1 is a perspective view of a disposable pump unit of the invention;

Figure 2 is a longitudinal cross-section of the disposable pump unit of Fig 1;

Figure 3 is a perspective view of a pump actuator for assembly with the pump unit shown in Figs 1 and 2;

Figure 4 is a cross-section of the assembled pump unit and pump actuator;

Figure 5 is a perspective view of the pump unit shown in Fig 1 additionally having a diluent inlet;

Figure 6 is a similar view to Fig 5, but in which the pump outlet has an integral convoluted path mixing section;

Figure 7 is a perspective view of a disposable pump unit of the invention showing the channels provided for prevention of occluded volumes of fluid in the pump;

Figure 8 is a perspective view of a disposable pump unit of the invention showing the closure between the pump unit and the reservoir; and

Figure 9 is a perspective view of a pre-formed membrane for use with the the disposable pump unit.

Referring to Figure 1 and 2, a dual-chamber disposable pump unit 100 is shown. A fluid inlet 14 splits to feed each of the two pump cells 1a, 1b comprised in a rigid body 2 having on a substantially flat surface thereof an area 3 containing a chamber

inlet port 4, the inlet port 4 being surrounded by a raised lip 5, and a concave cavity 6 defining one side of a pump chamber 7. The second side of the chamber 7 comprises a membrane 8 made of a flexible sheet material, e.g. low density polyethylene (LDPE), sealingly secured about its periphery to the aforesaid surface of the body 2 so as to enclose each fluid inlet area 3 and their respective concave cavities 6 such that fluid can pass from the inlet port 4, when open, to the respective concave cavities 6. Located in each concave cavity 6 of each pump chamber 1a, 1b is an array of chamber outlets 9. Each chamber outlet 9 is in fluid communication with a closable outlet port 10 surrounded by a raised lip 11.The flow paths from the two closable outlet ports 10 converge together into a single outlet 12. The two closable outlet ports 10 and the outlet 12 are together sealingly enclosed by a membrane 13 comprising flexible sheet material, shown to be integral with the membrane 8,. secured about its periphery to the aforesaid surface of the body 2.

Referring to Figure 3, a non-disposable pump-actuating unit 200 for the dual chamber pump unit 100 is shown. The actuating unit 200 comprises a rigid body 15 containing two concave cavities 16, each surrounded by a gasket seal 17. The concave cavities 16 and the gasket seal 17 are shaped such that they match the shape of the pump cells 1a,1b so that when placed in contact with them they form a seal around the circumference of the pump cells 1a, 1b. Located within each cavity 16 is a compressed air inlet/exhaust port 18 defined in part by cross-shaped channels extending over a substantial basal area of the cavity 16. Also located within each cavity 16 is a solenoid-operated armature 19 which extends through the body 15 and into the cavity 16. A pair of armatures 20 also extends through the body 15 adjacent to the cavities 16.

Referring to Figures 1, 2 and 4, the pump-actuating unit 200 is shown in Figure 4 to be releasably connected to the disposable pump unit 100 to form a complete pump. The cavity 16 in the unit 200 together with the membrane 8 forms an actuating chamber 21 connectable alternately to supplies of negative and positive pressure air *via* a passageway 22. Each cavity 16 in the pump-actuating unit 200 and its opposed cavity 6 in the disposable pump unit 100 together define a fixed volume of fluid that

will be displaced on each cycle of the pump. The sequence of operation of the pump is that each armature 20 extends so as to urge the membrane 13 locally onto the respective raised lips 11 of the outlet ports 10 thus closing the pump chamber outlet, and the armature 19 is spaced from the membrane 8 such that the flow path between the inlet port 4 and the concave cavity 6 is open. Armatures 19 and 20 have associated seals 19a, 20a, which prevent ingress of any substances past the armatures.

A first source of pump actuating fluid at a negative pressure, ie below ambient pressure, is connected to the actuating fluid port 18 via the passageway 22, the application of the negative pressure causing the flexible membrane 8 to be drawn towards and into the cavity 16 thereby drawing fluid into the latter from a reservoir (not shown) *via* the inlet 14 and the inlet port 4, the inlet port 4 being held open by the negative pressure tending to lift the membrane 8 locally away from the inlet port 4. The cross-shaped channels of the port 18 ensure that the membrane 8 can be drawn fully into the cavity 16 and prevents the membrane 8 from blocking the port 18 before the membrane 8 is substantially fully withdrawn into the cavity 16. When the membrane 8 is fully drawn into the cavity 16 and the volume defined by the cavity 16 and the cavity 6 is filled or substantially filled with the fluid to be dispensed, the armatures 19 and 20 are actuated such that armature 19 is moved towards the pump cell, locally pressing the membrane 8 against the raised lip 5 of the inlet port 4 to close the flow path between the inlet 14 and the pump chamber 7, and armature 20 moves away from the outlet port 10 allowing the membrane 13 to move away from the outlet port 10 of the pump cell outlet (12, Figure 1). Substantially at the same time, positive air pressure is applied to the membrane 8 *via* the port 18 which urges the membrane 8 towards and substantially fully into the cavity 6 whereby the fluid is pumped out through the outlet 12 *via* the outlet port 10. The pump filling/dispense cycle may then be repeated. The outlet armatures 20 are attached to stepper motors 20b which can vary the position of the each 20 in relation to the raised lip 11 of its respective outlet port 10 thereby allowing the opening of the outlet valve to be controlled to vary the outlet flow of the pump.

In operation, the two pump cells may be operated in opposite phase such that when one is dispensing the other is filling, the filling cycle preferably being faster than the dispense cycle such that there can be a slight overlap of the dispensing cycles to ensure constant output. If there are more than two pump cells then it is not necessary for the filling cycle to be faster than the dispense cycle.

Referring to Figure 5, a pump unit is shown which is similar to that shown in Figure 1 and operates in the same manner, but which has the additional feature of a diluent inlet 23 through which a diluent enters the pump cell and mixes with the pumped fluid to pass with it through the pump cell outlet 12 whereby diluted fluid is dispensed. The flow of the diluent is controlled by means of an external control valve (not shown) which may be variable and controlled to give a constant ratiometric mixture of pumped fluid to diluent.

Referring to Figure 6, a pump unit is shown which is similar to that shown in Figure 5 and operates in the same manner. However, in addition, it comprises a mixing section 24 downstream of the point at which the diluent is added. Where the pumped fluid is of a high viscosity (e.g. above 10,000 centipoises) it becomes increasingly difficult to obtain a homogeneous diluted fluid; the convoluted path 25 of the mixing section 24 is designed to shear the viscous fluid and create turbulence to ensure that the two components mix fully.

Referring to Figure 7 a rigid plastic pump unit is shown comprising of a fluid inlet 14 leading to two chamber inlet ports 4 from which there is a flowpath to the concave cavity 6 and its associated chamber outlet 9. Provided in surface of the concave cavity 6 and the flat area 3 are recessed grooves 26 which, should the flexible film (not shown) trap an occluded area of the pumped fluid remote from the chamber outlet 9, there will always be a channel for the fluid to be forced out of ensuring that the chamber is fully emptied every, thus giving a repeatable volumetric output. The pump unit shown in this figure has had all excessive plastic removed and designed for production by injection moulding techniques.

Referring to Figure 8 the rigid plastic pump unit of Figure 7 is shown further comprising an integrated static mixer 27 which is formed as a feature of the plastic moulding enclosed by the flexible film which is heat welded thereover. Additionally an array of obstructions 28 are provided between the outlet ports 10 and the static mixer 27 such that the fluid is sheared immediately prior to it admixing with the diluent entering via diluent inlet 23. Once admixed with the diluent the fluid passes through the static mixer 27 and is dispensed therefrom as a homogeneous fluid. In the fluid inlet (14, Figure 7) is a closure 29 which is rotatable by means of lever 30 to open or close the flow from the reservoir (not shown) to the inlet ports 4.

Referring to Figure 9 a pre- formed flexible membrane suitable to be heat welded to a pump zone of the invention is shown.